Ecology of Arizona Cottontop

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Abstract

This paper summarizes what is now known about the ecology and management of Arizona cottontop, *Trichachne californica,* a palatable, drought hardy, perennial grass that thrives under moderate grazing on semidesert ranges of the Southwest. Perennial culms that produce axillary shoots, favorable response to grazing, long life, and ability to grow both on warm- and cool-season moisture are valuable attributes of this species.

Keywords: Ecology, Arizona cottontop, grass

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Management Recommendations

To be successful, grazing management must regulate the season and intensity of use of range plants so the plants maintain a healthy vigorous condition. Obviously, knowledge of the effects of partial defoliation on plant growth processes is basic to the development of a management strategy. Because the rhythm of plant growth differs from species to species, a management strategy suitable to one species may be unsuitable to another.

The rhythm of plant growth of Arizona cottontop and its reactions to partial defoliation suggest this species is highly flexible in its adaptability to management strategies. Cottontop's high palatability at all seasons, its tolerance of relatively heavy use, its growth habit in which shoots in all stages of development are present throughout most of the growing season, its weak apical dominance and consequent prevalence of axillary shoot development, and the fact that axillary shoot growth is stimulated by removal of the growing point (partial defoliation) regardless of stage of development, all suggest cottontop will thrive with any management strategy, provided only that the intensity of use is held to a reasonable level.

Because cottontop is more palatable than most other grasses with which it is associated, it will be used more heavily than the associated species, and thus could easily be subjected to destructive intensities of use. Two management practices are recommended to enable cottontop to maintain optimum productivity:

1. If cottontop is the dominant, the utilization objective should be based on 50% use of cottontop. Use of associated species under these conditions will probably average about 35% (Cable and Martin 1975). If cottontop is not the dominant grass, stock to obtain about 40% use of the major species; use of cottontop should average a little less than 60% at this stocking level.

2. Defer or lighten grazing by about 50% during the growing season, 2 years out of 3. This will lighten the grazing impact on cottontop during the summer, but still provide the stimulus for axillary sprouting and increased productivity.

Research Highlights

Arizona cottontop is an important native forage grass of southwestern ranges of the United States. Extending southward to central Mexico, it is widely distributed within the semidesert shrub, desert grassland, chaparral, and oak-woodland types of the Lower and Upper Sonoran Life Zones. It grows on soils that vary in texture from clay loams to those that are loose and gravelly.

Cottontop is a climax dominant in the semidesert grassland type and, like other climax species, decreases in abundance on abused ranges. Cottontop, however, has several morphological and physiological characteristics that enable it to tolerate severe conditions of climate or use and that enhance its value as a range grass:

1. Individual culms and roots are long-lived, living for 3 years or more. Many individual plants live more than 15 years.

2. The culms exhibit low-level apical dominance. This, coupled with the large reservoir of buds at culm nodes on the elongated, as well as on the basal unelongated, portion of the culms, results in the sprouting of numerous axillary shoots. During its lifetime a basal culm can produce up to eight mature axillary shoots in addition to the terminal inflorescence.

3. Removing the growing point at the beginning of the summer growing season stimulates the sprouting and growth of axillary shoots, regardless of the stage of development of the shoot. The degree of stimulation is greatest during the first few weeks after treatment and decreases gradually during the remainder of the growing season.

4. Cottontop plants utilize both winter and summer precipitation. Although most herbage is produced during the summer growing period, essentially all basal culms produced in any given year sprout during the spring growing period; summer growth on most basal culms is merely a continuation of growth on shoots that sprouted in spring.

5. Shoots are produced throughout the growing season. New shoots are initiated from buds, both at

the base of the plant and on elongated internodes. New shoots on the upper part of the culms provide easily available green herbage relatively early in the growing period. Although sprouting of basal buds is normally confined to the spring growing period, axillary buds on the upper parts of the culms sprout throughout both spring and summer growing periods. Thus, most plants have shoots in all stages of development (from newly sprouting buds to those with a maturing panicle) at all times during the growing season.

6. Inflorescences mature throughout the summer growing period, starting about 3 weeks after growth begins (July or early August) and continuing as long as soil moisture is available (October in some years). Germinable "seed" will, therefore, be present whenever conditions are favorable for germination and establishment.

7. Cottontop is highly palatable to cattle and is preferred over most other species at all seasons of the year.

8. Cottontop tolerates relatively heavy grazing use over long periods. Dormant-season grazing averaging over 65% use for periods up to 15 years had no apparent effect on longevity, changes in basal area, or changes in plant height. However, continued heavy grazing during the growing season slows recovery following very dry years.

9. Cottontop, like most other semidesert species, extracts soil water rapidly when it is available, both in spring and summer. With its permanent root system in place, it can absorb soil water and begin growth quickly after an effective rain. It is also able to subsist for prolonged periods in soil with essentially no available water.

10. An established stand of cottontop competes strongly with velvet mesquite seedlings and, thereby, strongly deters the spread of mesquite into grasslands.

11. If a remnant stand of grass is present, marked improvement in production can be obtained by shrub control and lighter grazing use. Cottontop can be successfully reseeded on upland areas receiving at least 28 cm of annual precipitation, provided a good seed bed has been prepared. The use of cotton-box hoppers on seeding equipment is recommended for handling the fluffy cottontop seed. The recommended seeding rate is 5.6 kg/ha of hammermilled seed in the hulls.

12. Cottontop is only moderately affected by fires. If a wet summer follows a burn, cottontop will probably recover completely during the first growing season. If the burn is followed by a dry summer, complete recovery will probably require two summers.

13. Cottontop is highly flexible in its adaptability to management strategies, provided grazing intensity is held below 60%. Light summer use 2 years out of 3 is recommended to maintain optimum vigor while at the same time stimulating axillary sprouting to increase productivity.

Taxonomy

The type specimen for *Trichachne californica* (Benth.) Chase, (under the name *Panicum californicum* Benth.) was collected near Magdalena Bay, Lower California, in 1840. In the intervening years seven other names have been applied to this species: *Panicum lachnanthum, P. californicum, P. saccharatum, P. insulare* var. *lachnanthum, Valota saccharata, Digitaria californica,* and *Trichachne saccharata.* Under the International Rules of Botanical Nomenclature, published in 1933, *Trichachne californica* (Benth.) Chase was adopted as the valid name for this species (Hitchcock 1933 and 1950). Other authors (e.g., Gould 1968) now refer to this grass as *Digitaria californica.*

According to Fernald (1934), the genus *Valota* (*Trichachne* as used here) has existed for an extremely long time, as evidenced by the fact that the genus is found both in America and Australia, Australia having been cut off from its connection with other continents by mid-Cretaceous times. Fernald also states the species of the genus are few and stable (about 12), in contrast to the numerous unstable species of youthful genera of *Paniceae.*

Description

Arizona cottontop is a native, perennial, warm-season bunch grass with slender, erect stems from 30 to 100 cm tall (fig. 1). The culms are usually branched below, and arise from woolly, knotted, enlarged bases. The leaves are normally 8-13 cm or up to 25 cm long, with the upper leaves shorter than the lower. The outstanding physical characteristic of this grass is the slender silky-cottony seed head (composed of lance-shaped spikelets which grow in pairs) covered with long, silky, white (occasionally purplish) hairs (Judd 1962, Canfield 1934, U.S. Department of Agriculture 1937).

The cottontop root system is finely divided and much branched. It is concentrated mostly in the upper 20 cm of soil but extends downward to about 100 cm in coarse-textured soils (Blydenstein 1966). Average root diameter for 30 plants excavated was 0.6 mm. The number of secondary branches in the first 15 cm

averaged 32 for grazed plants and 80 for protected plants, and the number of roots per square centimeter, counted 8 cm below the base of the plant, averaged from 1.5 to 2.2.

Distribution

The range of Arizona cottontop on the American continent is from the southwestern United States to central Mexico (Hitchcock 1913). It has been collected from nine states in Mexico as well as Arizona, New Mexico, Texas, Oklahoma, and Colorado. It is reported from South America (Hitchcock 1950).

The species is found in the desert shrub formation of the Lower and Upper Sonoran Life Zones. It is found in the oak-woodland, chaparral, and semidesert grassland types in Arizona between 300 and 1,800 m elevation (Judd 1962, Humphrey 1960), where it grows on a variety of soils from clay loam to sandy loam and loose gravelly soils (Anderson et al. 1953, Schmutz and Smith 1976, Cable and Martin 1975, Cable 1979).

Figure 1.—Mature Arizona cottontop plant (90 cm tall).

In New Mexico it is one of many important co-dominants with black grama (*Bouteloua eriopoda*) in the desert grassland (Castetter 1956). It is also common on the plains and foothills of the drier mountains throughout the state (Wooton and Standley 1911). In southern New Mexico it is found associated with *Larrea* on limestone ledges and porphyritic hills and in the yucca-cactus association (Fosberg 1940).

Arizona cottontop in Texas is distributed throughout the state except for the Gulf Coast and the piney woods and post-oak savannah of east Texas. It is more common on the Rio Grande Plains, Edwards Plateau, and the trans-Pecos areas than elsewhere (Walker 1954, Gould 1962, Cory and Parks 1937).

In northeastern Sonora, Mexico, Arizona cottontop has been collected in the oak-grassland type (above the mesquite zone) from 1,100 to 1,800 m in elevation (White 1948).

Growth and Development

Seedling Development

Every cottontop plant starts as a seedling, which develops into the primary shoot, and from which additional shoots develop by tillering. The sequence of development of the parts of the shoot, as the first foliage leaf pushes out through the tip of the coleoptile, is for the leaf blade to start elongating first, followed in a few days by the sheath. During the first 20 days of seedling development in the greenhouse, additional leaves appear at about 3-day intervals (Cable 1971b). The first internode to begin active elongation starts about the 14th day, and successive internodes start elongating at about 3-day intervals. By the 7th or 8th day, the first adventitious root appears (fig. 2), and by the 20th day most seedlings have three or four adventitious roots (the permanent root system of the shoot). Axillary buds at the base of the primary shoot sprout into basal tillers (two only) by the 20th day, the two second-order basal tillers are elongating by the 40th day. Generally, there are three unelongated internodes left below the lowest elongating internode on the primary shoot, four on the first-order tillers, and six on the second-order tillers. Blade, sheath, and internode lengths on the seedlings generally increase from the lowest through the 7th or 8th, but they differ between the primary shoot and the first- and second-order basal tillers in that the mature length of blade, sheath, and internode at any given culm position is longest on the primary shoot, intermediate on the first-order tiller, and shortest on the second-order tiller.

Shoot Growth

Although cottontop is a warm-season grass and grows mostly during the summer, new basal shoots normally start their development in the spring growing period, go dormant during the May-June drought, resume growth with the onset of summer rains, and produce an inflorescence. Most shoots also produce axillary shoots from axillary buds, primarily on the upper part of the culm; these axillary shoots may mature during the same summer or go dormant over winter and mature the following spring or summer.

Cottontop culms (both basal and axillary) live more than 1 year, some 3 or more. They may also use from one to four growing periods (spring or summer) to complete their development from sprouting bud to mature inflorescence, depending largely on the amount and distribution of rainfall and depending on when the initiating bud sprouted during the growing period. Growth made during successive growing periods is usually separated by one or two very short internodes. These short internodes result when elongation of new internodes stops at the end of a growing period.

Numbers of internodes on mature reproductive culms vary from 3 to 21. In addition, basal culms may have from 3 to 15 unelongated internodes (<2 mm) at the base of the culm, below ground level. In general, axillary culms have about one-third fewer internodes than basal culms, and multiple-growing-period culms average 1-1/2 to 2 times as many internodes as those only one growing period old. Numbers of internodes on axillary culms are inversely related to how high on the parent basal culm the axillary shoot is attached.

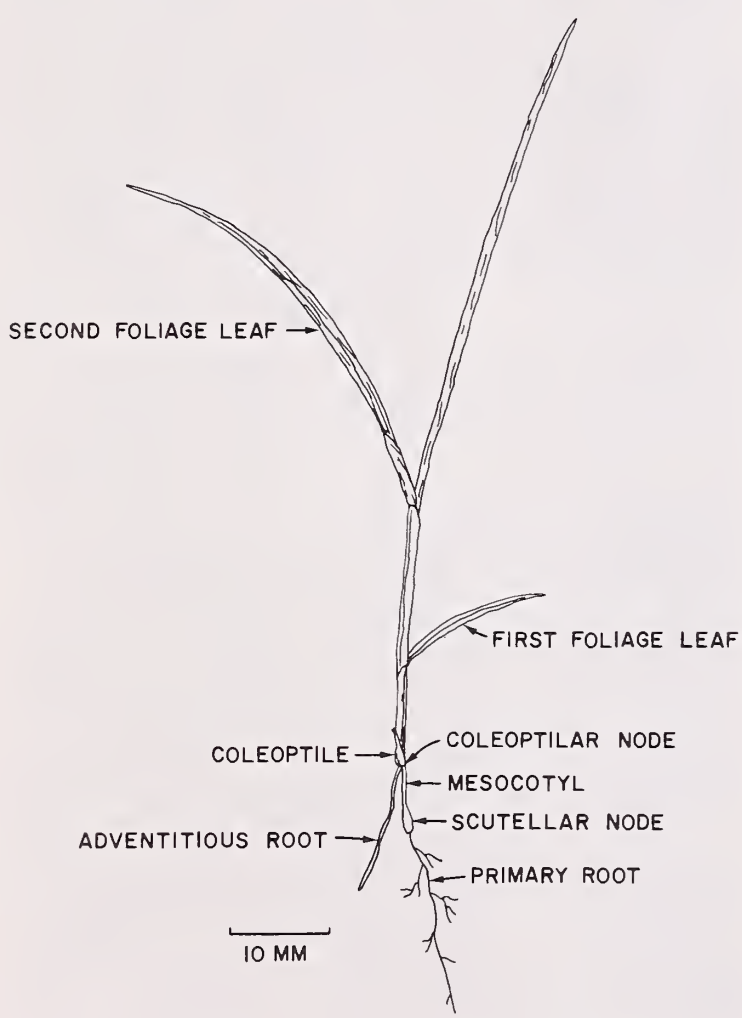

Figure 2.—Seven-day-old cottontop seedling.

Generally, the shortest internodes are at the base of the culm. Internode lengths increase gradually toward the top. The top two, especially the topmost (panicle internode), are greatly elongated. Variations in available soil moisture, however, affect these relations as, of course, does the number of growing periods required for the development of the culm. The length of the panicle internode is strongly correlated with the total length of the mature culm, because it comprises about 50% of that length.

In the field, new basal shoots elongate more or less uniformly for 5 or 6 weeks after summer growth starts (2.5-11 mm/day). Rate of growth then increases sharply (to 19-24 mm/day) for 7 or 8 days while the panicles are exserting and elevating, and then tapers off to zero within a few days.

From 13 to 18 days is normally required for the panicle internode to push the panicle out of the flag leaf sheath. About 70-80% of that elongation takes place in the first 7 days. Rate of elongation of the panicle internode is closely correlated with availability of soil moisture, but the internode will resume elongation if moisture is received within 3-4 days after elongation has stopped due to a moisture shortage. The maximum rate of elongation of the panicle internode measured on a single culm was 48.3 mm/day averaged over a 3-day period. Within any one 24-hour period, average hourly rates of elongation varied from a high of 1.95 mm/hour between 5 and 7 p.m., to a low of 0.27 mm/hour between 3 and 6 a.m. (fig 3).

Overall length of mature reproductive culms generally varies between 260 and 660 mm.

Buds

An axillary bud generally develops on each internode of the culm except two: the internode between the coleoptile and the first foliage leaf on the primary shoot, and that between the flag leaf and the panicle on all culms. Axillary buds on unelongated basal internodes (below ground level) differ markedly in appearance from those on elongated internodes of the culm. Basal buds are relatively short, circular in cross section, and not tightly appressed to the culm. Axillary buds are longer, slender, flattened, and tightly appressed to the culm. Basal buds are protected by dried scales and scale-leaves, with a short, dried

prophyll at the base. The prophyll does not elongate. Axillary buds are enclosed only by the green prophyll and the sheath of the subtending leaf. The prophyll elongates for a time after the bud sprouts. The inner leaves of the basal bud are thickened and fleshy, while those of the axillary bud are not.

Some buds live as long as the culms, 3 years or more; some dry up, some are damaged by insects, and some freeze. Basal buds and axillary buds near the ground are most susceptible to damage. The average basal culm will have eight live axillary buds and three live basal buds. By the time the basal buds sprout, they will average 3.4 axillary buds per basal bud.

Basal buds sprout primarily in the spring, producing the year's crop of basal culms, most of which mature the following summer. Axillary buds can sprout throughout both the spring and summer growing periods and also in early fall, depending on the availability of soil moisture.

Adventitious Roots

In the greenhouse adventitious roots start to develop from the lower internodes of the primary shoots within a week after seedling emergence (Cable 1971b). By the time the seedlings are 3-1/2 to 4 weeks old, they have an average of 4.8 adventitious roots. On basal buds, adventitious roots begin to develop about the time the bud sprouts in the spring. Additional adventitious roots appear throughout the spring growing period. Very few appear during the summer. Adventitious roots develop on some of the same internodes at the base of the culm from which basal shoots develop, although adventitious roots tend to develop more on the lower internodes and basal shoots on the upper internodes of the basal unelongated portion of the parent culm. Numbers of adventitious roots on mature basal culms varied from 0 to 12, averaging from 3.5 to 5 per culm. Live-tissue tests with tetrazolium chloride indicate many cottontop roots live 3 years; it is likely that some live longer. Active root systems of field-grown plants extend to at least 1-m depth (Cable 1979).

Leaves

New leaves are initiated by the apical meristem as nearly horizontal ridges partly encircling the growing point, and appearing alternately on opposite sides of the rudimentary axis. Each ridge soon develops into a collar-like structure. Only one or two such collar-like leaf initials are present at a given time. The newly developing leaf then grows up and over the apical meristem, forming a cowl-like hood over the growing point. Vertical elongation then raises the hood up away from the apical meristem. The ligule becomes visible as a row of bumps on the veins by the time the leaf is about 1 mm long. As soon as the ligule appears, the blade begins rapid elongation. The sheath begins

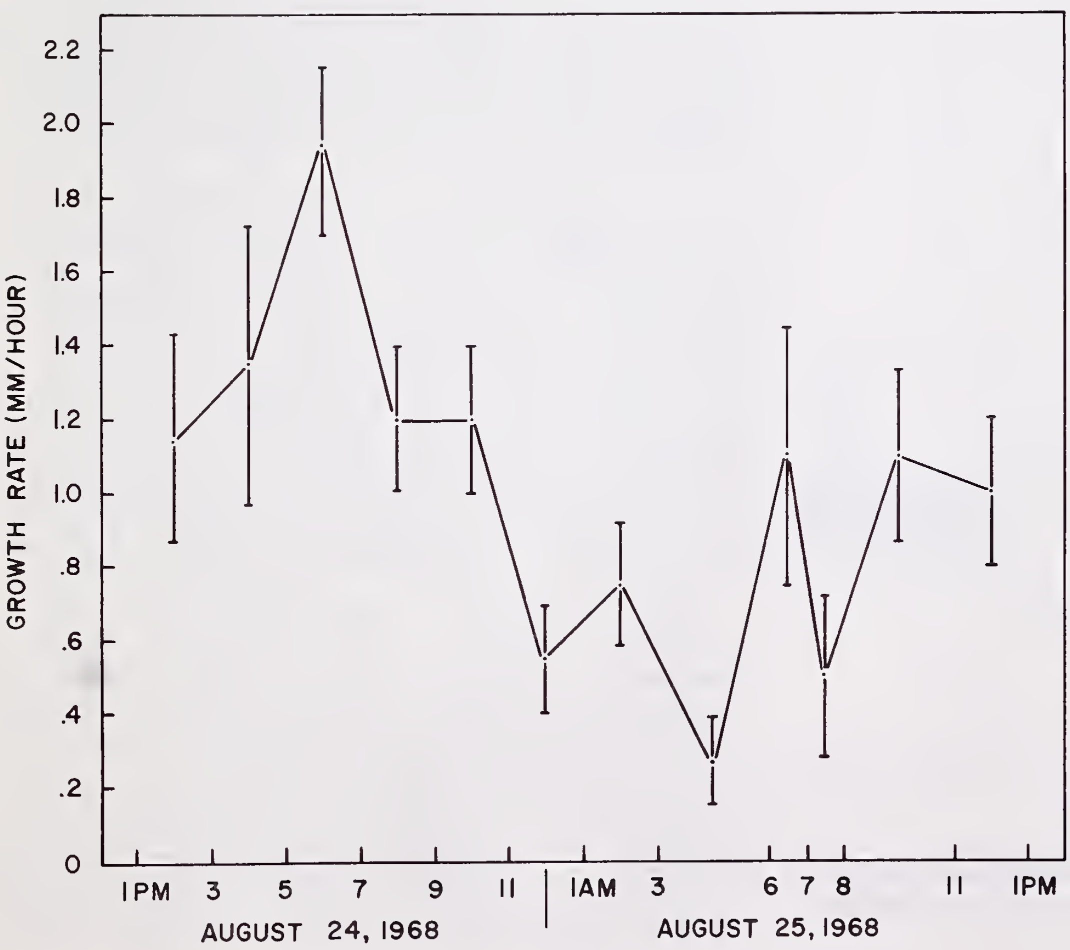

Figure 3.—Elongation of panicle internodes in millimeters per hour while panicles were exserting (means of 10 culms ±1 SE).

elongating when the blade has reached one-half to three-fourths of its mature length. The youngest six leaves are in the process of elongating at any one time (fig. 4). The youngest three or four of these are less than 1 mm long and are elongating very slowly. The other two or three exceed 1 mm in length and are elongating rapidly (all except the oldest are fully enclosed by the surrounding leaf sheaths). The blade is rolled during its elongating stage, but is fully expanded and elongated by the time it is fully emerged from the next lower sheath. In the field new leaves are initiated at the rate of one about every 4 days. Leaf blades remain fully green from 10 to 13 days. They start to dry in the same order in which they appear and require from 21 to 46 days to become fully dry. The rate of drying varies markedly: leaves 2 and 3 (below the flag leaf) consistently remain partly green much longer than any of the other blades.

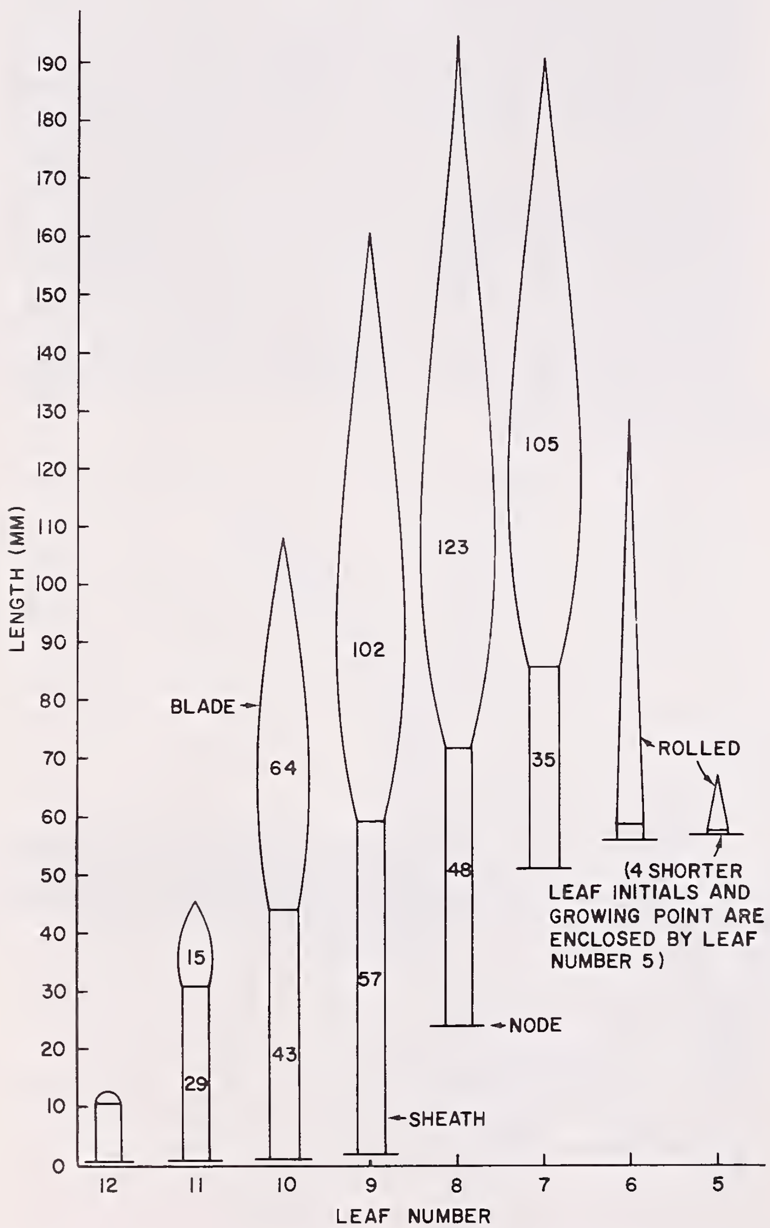

Figure 4.—Expanded diagrammatic view of vegetative shoot, showing relative positions and lengths of internodes, sheaths, and blades.

Lengths of leaf sheaths and leaf blades vary with position on the culm and whether the culm is basal or axillary. Also, taller mature culms tend to have longer leaves (sheath plus blade) than do shorter culms. The flag-leaf sheath is greatly elongated (to 202 mm), twice as long as the second sheath and three times as long as the third (fig. 5). Successively lower sheaths decrease slowly in length. Lengths of leaf blades are more variable than those of sheaths. Generally, the longest blade (up to 173 mm long) is on the third through sixth leaf from the top, with blade length decreasing toward both the top and bottom of the culm. However, on any given culm the longest blade can occur at any leaf position from the flag leaf to the seventh leaf. In the field differences in moisture availability at the time various leaves are elongating are responsible for the marked deviations from average lengths. Both sheaths and blades were shorter on axillary culms than on basal culms at all leaf positions. Leaf blades averaged 4.3 mm wide. Width was significantly related to blade length.

Inflorescences

The mature inflorescence of Arizona cottontop is a panicle consisting of a main axis with from four to nine erect branch racemes on which numerous spikelets covered with long, silky white hairs are borne. Normally, spikelets are borne in pairs, one short-stalked and one long-stalked, with each pair usually attached to the sinuous rachis at points of flexure. Panicles vary in length from about 50 mm to about 200 mm. The length of the panicle is strongly correlated with the length of the flag-leaf sheath, within which the panicle develops to its mature length before exserting.

The first indication that the vegetative growing point is about to become reproductive is an elongation of the growing point from the usual 0.07-0.09 mm to 0.15-0.20 mm long, accompanied by the formation of low ridges or swellings more or less circling the growing point (fig. 6). These are the primordia for the racemes. During the next 24 hours, while the young panicle is elongating to 3-5 mm, the raceme initials appear, and spikelet initials and glume primordia develop. By the time the panicle is ready to emerge from the enclosing sheath, it is fully elongated.

Most florets that reach anthesis (over half of cottontop florets are self-pollinated) exsert their anthers and stigmas during the first 3 hours after sunrise, on the part of the panicle that has emerged from the sheath during the previous 24 hours. By early afternoon flowering stops for the day. A few florets flower during the next week while the panicle is completing its exsertion and elevation. The last structure in the floret to complete its elongation is the ovary, or seed. The cottontop seed normally reaches

its mature length of about 1.7 mm in the soft-dough stage after the panicle is well elevated. However, cottontop seed can mature even though lack of soil moisture at the end of the growing period prevents the panicle from emerging from the boot. The topmost spikelets usually begin falling within 5-8 days after the panicle has fully emerged from the sheath. Usually, all seed will fall within 7-8 days after the first shatter.

Normally, inflorescences begin emerging from the boot 2-3 weeks after growth starts in the summer. A few inflorescences are usually produced during the spring growing period. The first panicles to emerge are always on basal and axillary culms that started their development the previous fall or spring (multiple-growing-period culms). Ordinarily, panicles from culms not starting development until after the summer rains begin do not start to emerge from the boot until about 6 weeks after growth starts. New panicles continue to be produced as late in the fall as soil moisture is available (October in some years). Individual basal culms, during their 3-4-year life, can produce from one to nine panicles, of which all except one (or sometimes all) will be on axillary branches.

Meristematic tissue can change from vegetative to reproductive over a wide range of developmental stages—with culm length as short as 2.5 mm and only 1 internode elongated to 2 mm or more, or with culm length as long as 158 mm and 11 elongated internodes. Generally, few short shoots will be reproductive; the percentage increases as culm length and numbers of elongated internodes increase.

Seed Habits

No published information could be found on the seed yield of Arizona cottontop. Anderson et al. (1953) state that seed can be harvested with suction equipment or bug catchers. Anderson says harvesting and processing the chaffy seed is difficult, discouraging seed production.

The U.S. Department of Agriculture (1948) lists cottontop seed as follows: weight, 718,000 seed per pound (1,583 seeds/gm); average purity, 32%; average germination, 44%; and seed longevity, intermediate. Forty samples of seed collected on the Santa Rita Experimental Range in 1964 averaged 550,000 ± 5,527 seeds per pound (1,212/gm, ± 12) with rachises and glumes in place. Germination 6 months after collection ranged from 72 to 92%.

Seed longevity was tested by germination trials on seven batches of cottontop seed kept under uncontrolled storage conditions at the Santa Rita Experimental Range headquarters for periods varying from 3 to 30 years. These tests showed seed maintained a relatively high germination (over 80%) for about 3 years. Germination declined about 6% per year for the next 12-14 years, to less than 10%. Seed in

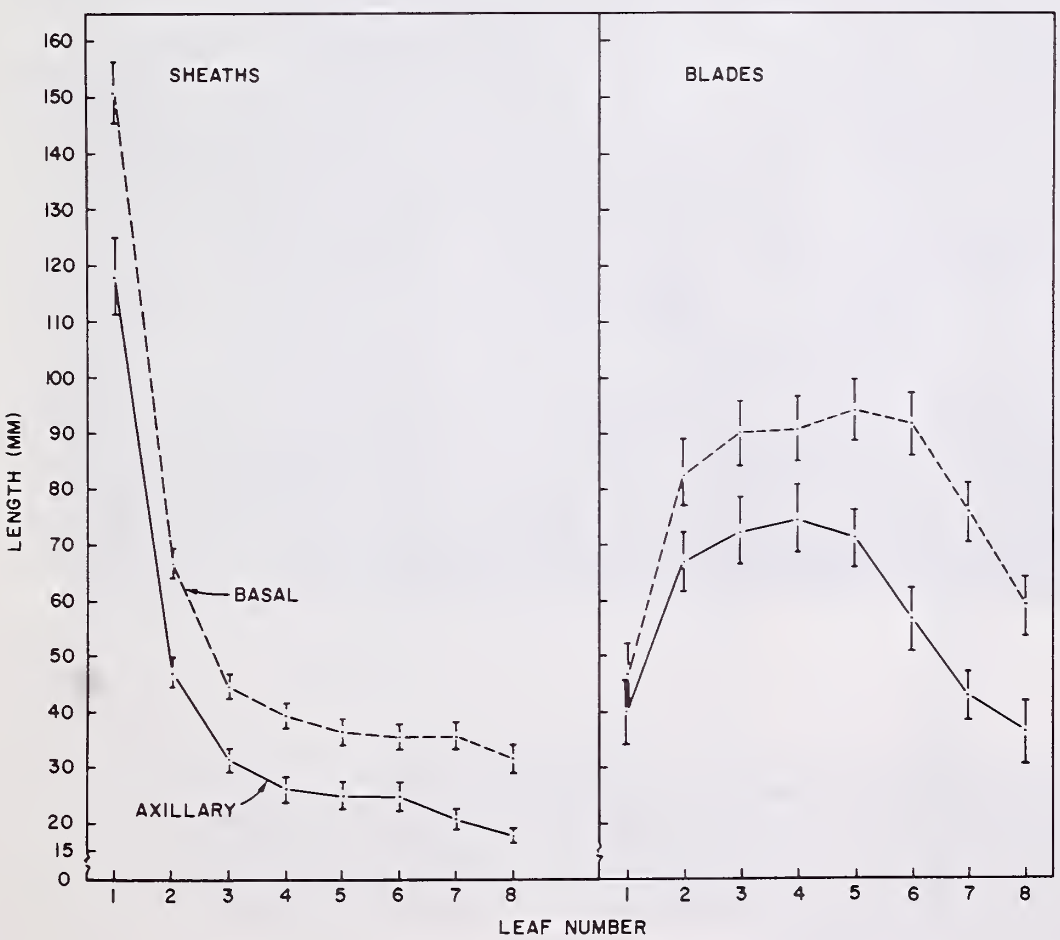

Figure 5.—Mean lengths of sheath and blade for upper 8 leaves on 28 mature basal culms and 14 mature axillary culms (±1 SE) (1 = flag leaf).

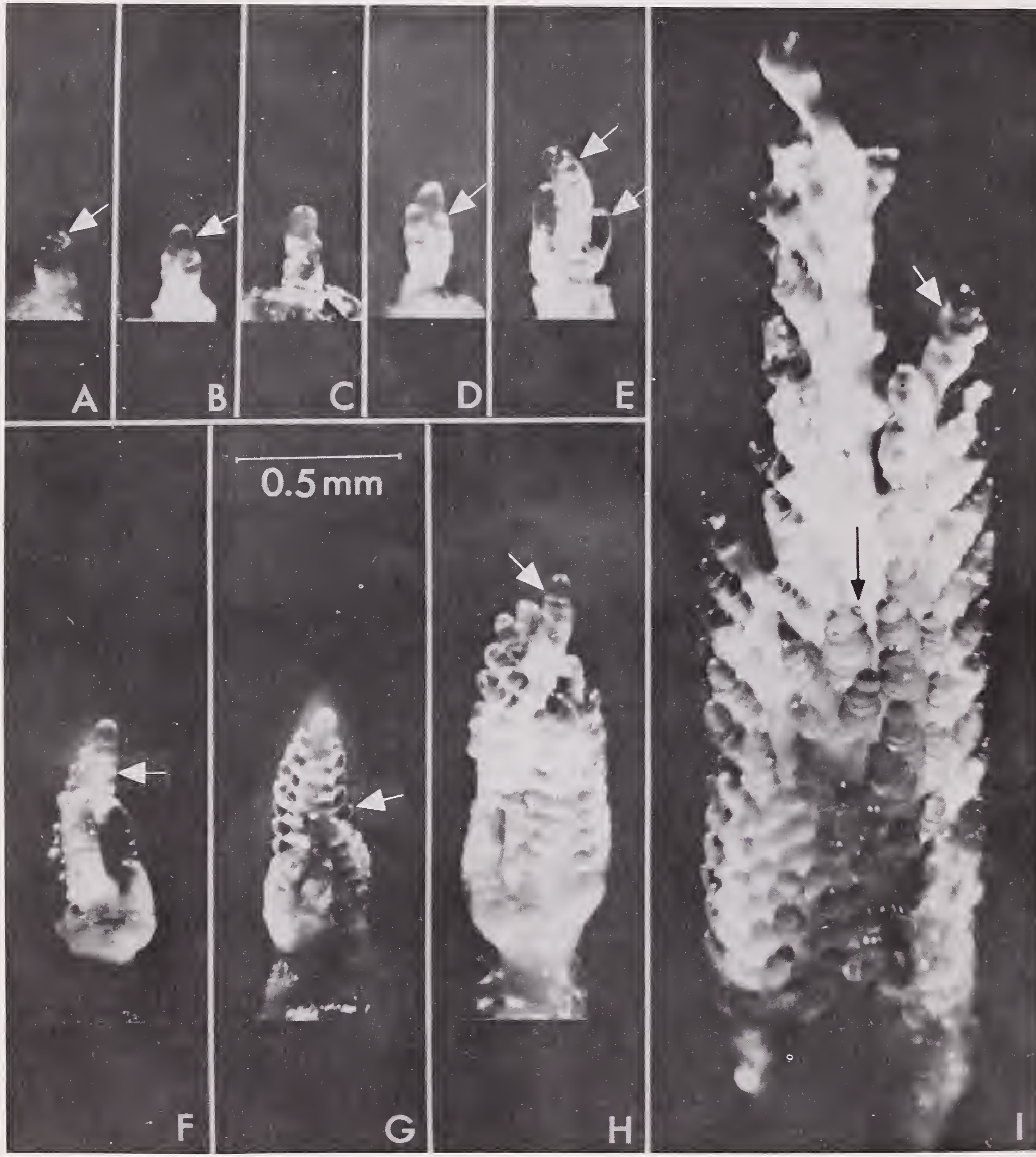

Figure 6.—Stages in the morphological development of shoot apices of Arizona cottontop: (A) vegetative growing point with cowl-like hood pushing up from far side; (B, C) vegetative growing points elongating preparatory to becoming reproductive; (D) raceme initials forming around reproductive growing point; (E) spikelet initials forming on upper part of main axis; branch racemes smooth; (F, G) spikelet initials showing on all branch racemes; (H) glume primordia on upper protuberances; (I) advanced stage of flower development, with floret protuberances in various stages of development.

uncontrolled storage at the Sierra Ancha Experimental Forest for 25 years showed 25% germination (Tiedemann and Pond 1967). Physiological and morphological differences and differences in storage conditions probably are responsible for the large differences in viability after prolonged uncontrolled storage.

Establishment and Longevity

Detailed 17-year records of seedling establishment on charted meter-square quadrats on the Santa Rita Experimental Range show that, although some cottontop seedlings were recorded in each of the 17 years, numbers of new plants averaged only 0.5 and 0.9 plants per meter-square quadrat on ungrazed and grazed quadrats, respectively. This was the lowest frequency for all species observed. However, first-season survival was relatively high, 46% on ungrazed quadrats, and 39% on grazed quadrats (Canfield 1957).

Arizona cottontop is a comparatively long-lived grass. Quadrat records from 17 years of charting on the Santa Rita show that some plants lived as long as 11 years (Canfield 1957). Arizona cottontop and sprucetop grama (*Bouteloua chondrosioides*) rated highest among 11 perennial grasses in survival during the first 4 years of life; from 17 to 21% of cottontop plants lived to 4 years of age. The percentage of plants surviving at any age was somewhat higher on ungrazed than on grazed quadrats through the fifth year; beyond that age survival was higher on grazed quadrats.

More recent records of cottontop longevity were obtained on the Santa Rita for 250 plants individually tagged in 1960 and 1961. Two hundred plants tagged in 1960 were in a pasture grazed annually during the winter-spring season. Fifty plants tagged in 1961 were in a permanent cattle exclosure. Basal diameter and height of each plant were measured twice yearly for 15 years. At the time of tagging, basal diameters of these plants varied from 1.2 to 14.0 cm. After 15 years, 31 of the 200 grazed plants (15.5%) were still alive, including one of the largest and one of the smallest plants originally tagged. Of the protected plants 17 of 50 (34%) were still alive, including the largest plants originally tagged. These results differ from those reported by Canfield (1957). Several of the grazed plants had their largest basal diameter at the end of the period. Obviously, some cottontop plants live considerably longer than 15 years. The protected plants that survived 15 years generally had much smaller basal diameters at the end than at the beginning of the period, and most were in poor vigor at the end.

Annual mortality rates show two major peaks (25.6% in 1963-64 and 27.2% in 1969-70) and two major lows (2.3% in 1967-68 and 1972-73) (table 1). These year-to-year differences in mortality may primarily reflect internal physiological conditions, because they are not correlated with observed changes in precipitation, intensities of utilization, or relative size of plant. It may be significant that the two major lows were in years with unusually high February-May rainfall. All longevity groups were grazed relatively heavily (45-55%) during the first 7 years and relatively lightly (20-30%) during later years.

Height-Weight Relations

Accurate determinations of the degree of utilization of grass plants are based on the height-weight relations characteristic of each species. From this relationship and records of actual use of individual plants on grazed range over a period of years, permissible levels of utilization can be determined. The height-weight relationship of Arizona cottontop was determined by air drying and weighing 2.54-cm segments of 15 cottontop plants. These 15 plants varied from 34 to 85 mm basal diameter, 66 to 99 cm total height, and 14.2 to 75.6 gm total weight. For these plants, the lower 40% of total height contained nearly 90% of the total weight (fig. 7). The long leafless panicle internode accounted for 34% of the average ungrazed plant height, but less than 2% of the plant weight.

To increase the usability of the height-weight data in determining utilization of individual plants, the data were converted into a nomograph (fig. 8) with which

Table 1.—Mortality among 200 tagged Arizona cottontop plants, 1961 to 1975

Year of death	Alive at start	Died during year		Mean use
		no.	*percent*	*percent*
1961-62	200	28	14.0	51
62-63	172	12	7.0	48
63-64	160	41	25.6	43
64-65	119	18	15.1	44
65-66	101	9	8.9	42
66-67	92	4	4.4	55
67-68	88	2	2.3	50
68-69	86	5	5.8	41
69-70	81	22	27.2	46
70-71	59	10	17.0	44
71-72	49	5	10.2	38
72-73	44	1	2.3	33
73-74	43	2	4.6	37
74-75	41	6	14.6	37
1975+	35	4	11.4	35

the percent use by weight can be determined directly from the ungrazed plant height and the grazed stubble height.

Ecological Relations

Successional Status

Early studies of perennial grass composition on the Santa Rita Experimental Range included areas heavily grazed, conservatively grazed for 5 years, and protected for 5 and 25 years, providing a basis for inferences on the successional status of cottontop and associated grass species (Canfield 1948).

On a relatively large segment of the Experimental Range, at elevations from 900 to 1,400 m with annual precipitation averaging from 30 to 55 cm, Canfield found that, after long periods of protection, the composition was dominated by tall, coarse-stemmed grasses such as Arizona cottontop, side-oats grama (*Bouteloua curtipendula*), and black grama. He concluded these species were probably "important members of the semidesert grassland climax vegetation." On the upper portion of the area studied, cottontop was the dominant species on protected areas, greatly surpassing every other grass in abundance and comprising one-third of the total composition. On the lower portion of the area cottontop and black grama were about equally abundant on protected areas and made up about one-half of the total cover. Canfield also noted that increasing abundance of Arizona cottontop was the most conspicuous sign of range recovery under either conservative grazing or total protection.

Response to Precipitation

Within its geographical range, cottontop grows in a wide variety of precipitation regimes, from a strongly bimodal type with spring and summer maxima separated by dry periods, as in southern Arizona, to a

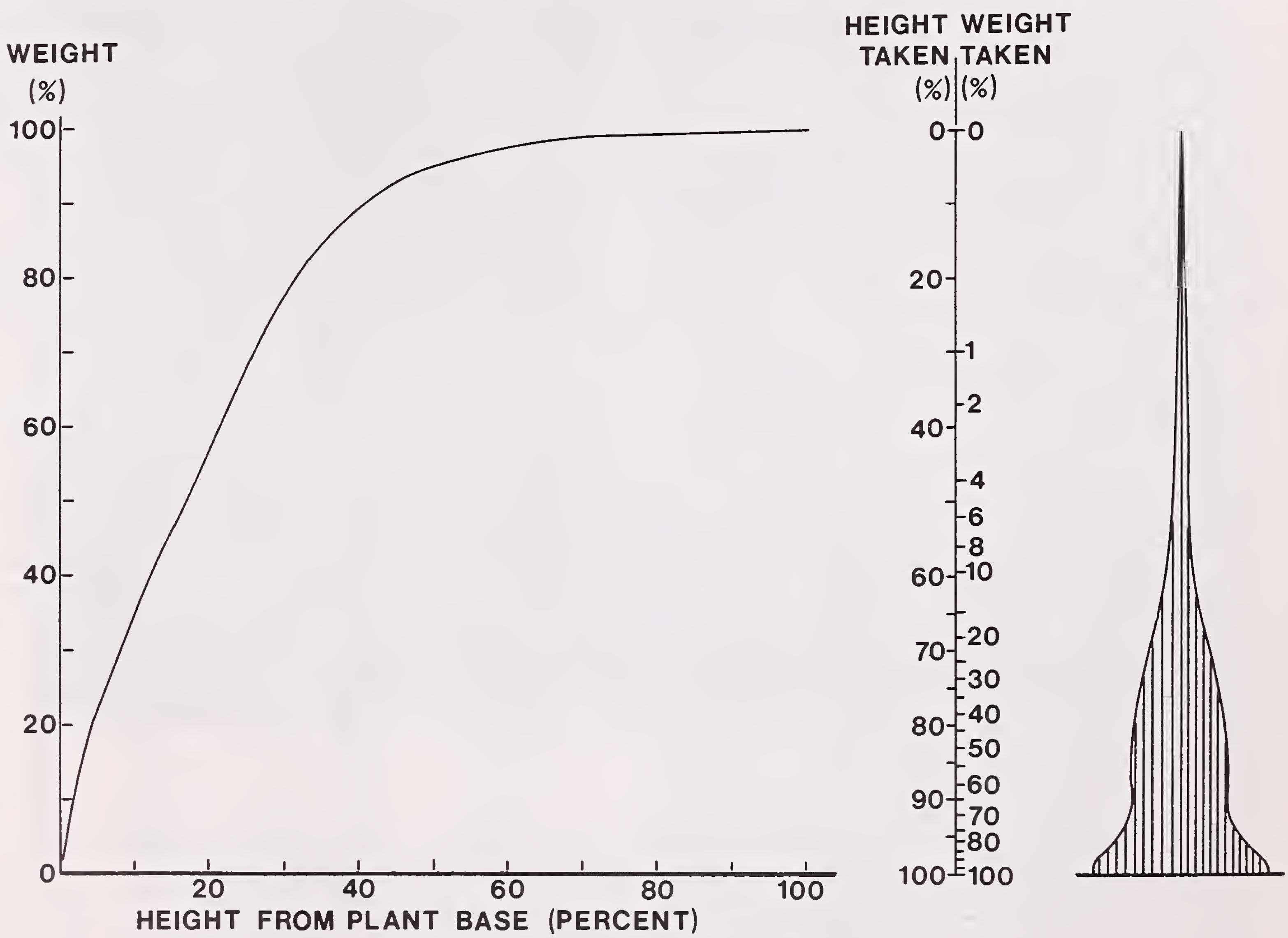

Figure 7.—Height-weight relationship and volume distribution in relation to height for 15 Arizona cottontop plants.

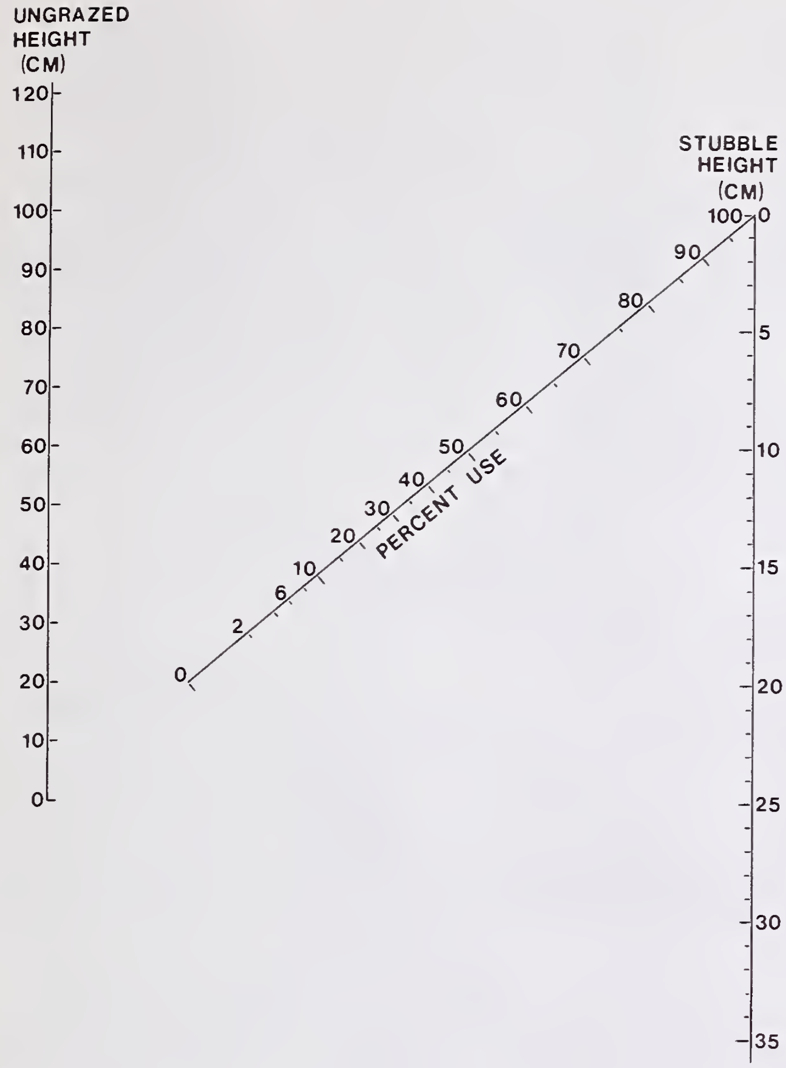

Figure 8.—Percent use by weight of Arizona cottontop for ungrazed heights to 120 cm and stubble heights from 0 to 35 cm. To use, lay straight edge between ungrazed height and stubble height and read percent use on diagonal scale in center.

high-summer, low-winter type, as in Texas, Oklahoma, and eastern New Mexico. Because cottontop is a warm season grass, adequate summer rainfall would seem necessary for vigorous stands.

The specific influence of precipitation on production of perennial grasses, including Arizona cottontop, was investigated for one precipitation regime on the Santa Rita Experimental Range (Cable 1975, Cable and Martin 1975). Over a 10-year period perennial grass production was most highly correlated with rainfall for August of the current summer, and next most highly with that for the current June-August period. However, rainfall for the June-September period of the previous summer also strongly affected grass production of the current summer—not directly, but as an interaction: the product of current multiplied by previous summer's rainfall. Thus, the effectiveness of a given amount of current-summer rainfall in producing forage is strongly affected by the amount of rainfall received the previous summer. Changes in the product of previous June-September rainfall multiplied by current August rainfall accounted for from 64 to 90% of the year-to-year changes in perennial grass production.

The influence of many other precipitation attributes on grass production was also investigated, including various expressions of winter precipitation (alone and in combination with summer rainfall) as well as expressions involving size and spacing of storms. None of these variables was as closely correlated with production as the interaction rainfall term alone.

Response to Light

Arizona cottontop and several other semidesert grasses grow better in full sunlight than they do under artificial shade (Tiedemann et al. 1971). Artificial shade treatments which reduce full sunlight by 20% increments show that each successive 20% reduction in light, from 100 to 20% of full sunlight reduces herbage yield of cottontop by about 20% of the full sunlight yield. Yields of black grama are reduced more than those of cottontop; yields of bush muhly (*Muhlenbergia porteri*) and plains bristlegrass (*Setaria macrostachya*) less. The reductions in herbage yield are accompanied by corresponding reductions in root weight, but levels of total available carbohydrates are not affected. Length of leaf blades of cottontop increase about one-third in shade, and numbers of inflorescenses decrease. In a previous study, however, Tiedemann (1970) found production of cottontop and two other species was higher for plants growing under mesquite trees than in the open. Thus, while shade by itself reduces herbage production of cottontop, apparently the growth stimulating effect of higher nutrient levels in the soil under the trees than in the open, more than makes up for the restrictive influence of shade on production.

Response to Soil

Soil texture.—Arizona cottontop grows on a wide variety of soils, from clay loam to sandy loam and loose gravelly soils. It is also found on limestone ledges and porphyritic hills. However, it grows better on some soils than others. On the Santa Rita Experimental Range cottontop is abundant and very productive on Whitehouse and Comora soils, slightly favoring the Comora. It is much less abundant on Coronado soils (Cable and Martin 1975). Whitehouse is characterized by clayey subsoils and well developed horizons; Comora, by sands or sandy loams in the subsoil and weak profile development. Coronado is a shallow, stony, and cobbly soil of the steeper slopes.

Soil water.—The use of soil water by Arizona cottontop coincides with the two main periods of plant growth; one in the spring, using accumulated winter precipitation, and one in the summer, using current summer rainfall (Cable 1979).

Although summer is the main period of perennial grass growth, soil water is readily used in the spring when available. Above normal water supplies in the spring of 1973 provided 9.6 cm of available water in the upper 1 m of soil for the cottontop plants studied. During the 70-day depletion period from March 22 to May 30, the plants used 76% of the available water. Water was extracted uniformly within the upper 75 cm, 0.11% by volume per day, slightly slower at 100 cm (table 2). Bare soil losses were about half as great, highest at 25 cm and decreasing at deeper depths, especially at 100 cm.

In the summer, evapotranspiration demand is higher than in spring, extraction rates are higher, and soil water is depleted faster. During both spring and summer growth periods, available soil water is reduced to 1-2% by volume throughout the profile by the end of most depletion periods, and to essentially no available water after unusually dry periods.

Thus, cottontop is able to use water rapidly when available. It is also able, when necessary, to exist for relatively long periods with little or no available water. During such periods, which may last for several months during dry spring or summer growing periods, water loss at cottontop plants is essentially the same as water loss from bare soil.

Response to Burning

Cottontop is intermediate among semidesert grasses in its susceptibility to damage from burning (Reynolds and Bohning 1956, Cable 1967). Basal intercept of perennial grasses decreased during the relatively dry growing season immediately following burning, but had essentially recovered by the end of the second growing season. A second fire 3 years after the first did not adversely affect the grass plants because of low fuel accumulation in the interim and a wet growing season following the fire.

Competitive Interactions

An established stand of cottontop competes strongly with velvet mesquite (*Prosopis juliflora* var. *velutina*) seedlings. In a study of 100 velvet mesquite seeds planted per treatment, only 7 seedlings became established in a stand of cottontop, compared with 56 on an adjacent bare area (Glendening and Paulsen 1955). One year after planting, mesquite seedling survival averaged 18% on the cottontop plot and 80% on the bare area. The situation is reversed, however, in mature stands of velvet mesquite. The reduction in cottontop production caused by competition from mesquite is most clearly shown by the large increases in cottontop production that result when an existing stand of mesquite is controlled. On one study area native perennial grass production (mostly cottontop) increased from less than 224 kg/ha in the year that the mesquite were first sprayed with herbicide to over 896 kg/ha (mostly cottontop) in the fall of the second year, after the second spraying (Cable 1971a, 1976). In another study, in which existing stands of mesquite were thinned to four levels (62, 40, 22, and 0 trees/ha), native perennial grass production (mostly cottontop) was five to six times higher by the end of the second growing season (fig. 9) on plots where all mesquite was killed than on plots where no mesquite was killed. Grass production was significantly higher with each successive level of thinning (Parker and Martin 1952). Cottontop production increased much less following mesquite control on areas with initially less dense mesquite and more dense grass cover (Cable and Martin 1975) and on areas with less than 33 cm of annual precipitation (Martin and Cable 1974).

Competition from burroweed (*Haplopappus tenuisectus*) reduces cottontop production comparatively little. Stands of 25,000-30,000 burroweed plants/ha reduced cottontop production by about 25% (Cable 1969). The relatively small impact of burroweed on cottontop was attributed to the relatively few burroweed feeder roots in the upper 15-

Table 2.—Soil water use (percent by volume) by Arizona cottontop between March 22 and May 30, 1973, following good winter recharge on the Santa Rita Experimental Range

At plants				Bare soil			
Depth	Available water	70-day use	Rate per day	Depth	Available water	70-day use	Rate per day
cm	*percent by volume*			*cm*	*percent by volume*		
25	9.20	7.60	0.110	25	9.10	5.30	0.080
50	9.40	7.80	.110	50	9.00	4.10	.060
75	9.70	7.50	.110	75	9.20	3.80	.050
100	10.20	6.40	.090	100	6.70	1.00	.010
Mean	9.63	7.33	.105	Mean	8.50	3.55	.051

Figure 9.—Effect of mesquite removal on perennial grass cover: (A) Undisturbed stand of 340 mesquite per ha, September 1945; (B) Adjacent area where mesquite were eliminated in March 1945, showing striking first season increase in Arizona cottontop, September 1945.

20 cm of soil where grass roots are concentrated, and to the fact that the primary period of growth of burroweed is in the spring. Summer growth of burroweed usually does not begin until cottontop growth is well advanced. In fact, because of its earlier summer growth, cottontop competes with burroweed enough to reduce crown cover increase of burroweed during the summer by about one-half.

Competition between summer annual grasses and cottontop follows a pattern similar to that with burroweed, in that annual grass production is about two-thirds less with cottontop competition than without. Annual grass competition can reduce cottontop production by about one-fourth (Cable 1969).

Among the various associated native perennial grasses, competition does not appear to be a dominant factor; the species coexist on many kinds of sites and in many mixtures. The evidence is compelling, however, that introduction of some exotic grasses can drastically upset the relative stability of the native perennial grass stand in the semidesert. On the Santa Rita on ranges between 1,100 and 1,400 m elevation and receiving 33-43 cm of annual rainfall, Lehmann lovegrass (*Eragrostis lehmanniana*) has almost completely replaced the former native grass stand, including cottontop within 10-12 years after seeding (Cable 1971a, 1976). It will eventually invade and replace adjacent unseeded native stands. None of the native perennial grasses, including cottontop, can compete successfully over the years with Lehmann lovegrass on areas to which it is well adapted.

Response to Insects

Schuster (1967) lists Arizona cottontop as one of 38 native and introduced grasses affected by rhodesgrass scale (*Antonina graminis*). In greenhouse tests Schuster found the yield of glabrous cottontop plants was reduced 88.3% by the scale infestation. The scale killed 85% of the plants during the test. Pilose cottontop plants, on the other hand, decreased only 28.6% in yield, and no plants were killed. No indication of actual field occurrence or damage to cottontop from rhodesgrass scale was given.

Physiological Relationships

Osmotic Relations

Osmotic value is a measure of the total osmotic pressure found in plant cells, including turgor pressure and suction pressure. As such, it reflects the climate, soil, and especially the moisture supply characteristics of the environment.

Love (1934) studied the osmotic value of foliage of several grasses, including Arizona cottontop, at three locations on the Santa Rita Experimental Range from June until December 1933. He found osmotic values varied inversely with variation in precipitation, although diurnal fluctuations in osmotic values were influenced also by air and soil temperatures, wet-bulb depression, and solar radiation. The highest and lowest osmotic values recorded for Arizona cottontop were 42.97 and 11.60 atmospheres. Consistently lower values were recorded at the location where greater amounts of water were available. Grasses at this location also produced a greater amount of growth than those at either of the other stations.

Love also found total weekly precipitation of at least 5 cm was required to initiate growth of perennial grasses (including cottontop). From measurements of soil moisture and wilting point, he concluded grasses apparently "do well with the total soil moisture below the calculated wilting coefficient."

Water Requirement

McGinnies and Arnold (1939) determined the quantity of water required for the production of a unit weight of dry matter, exclusive of roots, for a variety of grasses, forbs, and shrubs typical of the semidesert grassland on the Santa Rita Experimental Range. They found two periods of growth during the year. The main period of growth was in the summer, from late June into September. With optimum conditions plants often developed to full bloom stage in from 10 to 30 days. The second period of growth, occurring sometime between November and April, was very indifinite as to beginning and ending, depending on the occurrence of favorable combinations of soil moisture and temperature.

Arizona cottontop was found to have a generally moderate water requirement, with a tendency for high production in late spring and during summer months of moderate temperatures and moderate to low humidity. It made poor growth during excessively hot dry weather and only moderate growth under hot humid conditions. The lowest water requirement was recorded in July and early August of 1936, a relatively moist period with average summer temperatures.

A more recent study of soil water use by several semidesert grasses and shrubs showed that cottontop extracted water from a 100-cm profile at an average rate of 0.105% by volume/day during a 70-day depletion period following good winter recharge, and 0.099% by volume/day during a wet summer. Rates of loss were similar at 25-, 50-, and 75-cm depths during the spring depletion period (table 2). At 100-cm extraction was slower during the early part of the

period and more rapid during the latter part (Cable 1979). These semidesert species are able to extract water rapidly from soil when it is available, and to subsist for prolonged periods in soil with essentially no available water.

Economic Considerations

Abundance and Yield

Abundance.—Generally, abundance of Arizona cottontop has been referred to in qualitative terms, as being "common," but seldom as "abundant" (Anderson et al. 1953; Wooton and Standley 1911). Griffiths et al. (1915) stated, however, "In many situations, especially in the moister places in the desert foothills of Arizona and the plains of Texas, it grows almost pure over large areas and makes a striking appearance."

Early descriptions of the vegetation of the Santa Rita Experimental Range by Griffiths (1901), Wooton (1916), and Hensel[2] in 1917 either made no mention of Arizona cottontop or indicated it was a minor species. Griffiths (1904) does mention the presence of cottontop in the open foothills at the upper edge of the Experimental Range "growing under the protection of bushes along the arroyos." He also states cottontop "sometimes covers considerable areas of open land" and includes a photograph taken in the fall of 1902 south of the Range "in McCleary's pasture" (the south-central part of present pasture 8), showing a good stand of cottontop headed out. In the legend to this photo accompanying his annual report of 1902, Griffiths[3] refers to this stand as "one of the best growths of cottontop I have ever seen."

In ensuing years the relative importance of cottontop on most of the Santa Rita increased greatly, apparently in direct response to gradually decreasing grazing pressure. Between 1915 and 1935, cottontop made up only 2% of the composition on depleted ranges, compared to from 19 to 26% on areas grazed conservatively or protected from grazing (Canfield 1948). In 1941 McGinnies et al.[4] ranked Arizona cottontop eighth of 14 perennial grasses in relative abundance on the Santa Rita. Reynolds in 1959 showed cottontop as third in abundance on ranges between 1,200 and 1,500 m elevation, tied for sixth place on ranges between 1,000 and 1,200 m, and tied for second place on ranges below 1,000 m.

During the 10 years from 1957 to 1966, on ranges between 900 and 1,200 m on the Experimental Range, cottontop was the dominant perennial grass, accounting for 36% of the total perennial grass production, over twice that of the next species (Martin and Cable 1974). During the same period, on ranges between 1,200 and 1,500 m, cottontop was the second most productive species, below slender grama (*Bouteloua filiformis*) (Cable and Martin 1975).

Apparently, the heavy grazing and drought to which southern Arizona was subjected immediately before and after the turn of the century (Griffiths 1901, 1910) had nearly eliminated Arizona cottontop as a component of the grass cover, except on more favored sites or protected spots. More conservative management in recent years has permitted cottontop to regain its former dominance on the Santa Rita. A similar recovery of cottontop has been noted on other areas. Near Oracle, Ariz., on ranges 1,100 m elevation and 38-40 cm precipitation, cottontop was nearly absent in 1941 (Schmutz and Smith 1976). By 1969 cottontop was present in small amounts on a grazed range and was the most abundant grass on a protected range. Schmutz and Smith concluded cottontop "is one of the most important climax grasses on this site."

Yield.—Arizona cottontop has produced over 672 kg/ha on favorable sites in wet years on the Santa Rita. Long-time averages over larger areas are, of course, much lower. On six large pastures covering 11,000 ha between 900 and 1,200 m elevation, receiving from 25 to 36 cm annual precipitation, cottontop was the most productive species, averaging 21.3 kg/ha during a 10-year period, and constituting 36% of the total perennial grass production. Production varied from year to year, with changes in rainfall, but the relative variation was low: a coefficient of variation of 40% compared to a range of from 35 to 86% for associated species. On four small pastures totaling about 1,300 ha, at 1,200-1,500 m elevation, and with 38-43 cm annual precipitation, cottontop production averaged 70 kg/ha during the same 10-year period. This constituted 14% of the total perennial grass production, and was next to the highest production by a single species. Productivity of cottontop in terms of weight of herbage per acre per 0.01% of basal intercept, was intermediate between the smaller bunchgrasses and the tall larger bunchgrasses (table 3) (Cable and Martin 1975).

[2]*Hensel, R. L. 1917. Natural revegetation of the Santa Rita Experimental Range. (Typewritten report on file at USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Tempe, Ariz.*

[3]*Griffiths, David. 1902. A report upon range work in Arizona in 1902. (Typewritten report, plus supplement containing 78 figures, on file at USDA For. Serv., Rocky Mt. For. and Range Exp. Stn., Tempe, Ariz., 76 p)*

[4]*McGinnies, W. G., K. W. Parker, and G. E. Glendening. 1941. Southwestern range ecology. U.S. Dep. Agric., For. Serv., Southwest. For. and Range Exp. Stn. (mimeo), 201 p.*

Nutritive Quality and Palatability

The protein content of young and early-mature cottontop herbage averaged 8-10%, nearly twice that of mature material. The protein content of young cottontop material reported by Fudge and Fraps (1945) was next to the lowest of 23 species of grasses tested. Phosphoric acid and lime content of cottontop was also near the bottom of the list. Fudge and Fraps rated the average protein and phosphorus content of young cottontop as "fair" and calcium content as "good."

Crude protein content of cottontop foliage clipped at approximately monthly intervals on the Santa Rita varied between 3.6 and 5.7% from November to June, but rose to 12.8% in the middle of the summer growing season (Cable and Shumway 1966).

A comparison between nitrogen content of the soils and protein content of the grasses showed very little relation between the two variables. Protein in 54 samples from soils containing less than 0.061% nitrogen was as high as in those produced on soils which contained more than 0.18% nitrogen. In another study Fudge and Fraps found protein in the grasses was significantly related to total nitrogen in the soil in 15 out of 44 comparisons. Content of phosphorus and lime in the grasses tended to vary with phosphoric acid and active lime content of the soils.

The available published analyses of cottontop herbage are summarized in table 4.

Moisture content of herbage of Arizona cottontop collected on the Santa Rita at monthly intervals between September 5, 1956, and June 3, 1957, varied from a high of 45.2% on September 5 to a low of 15.6% on May 1, with a 10-month average of 23.7% (Cable and Bohning 1959). Moisture content followed the rainfall pattern: highest in summer, with a smaller high in winter, separated by periods of low moisture content (lowest in early summer).

Table 3.—Average production and average productivity per unit of basal intercept for the 17 most common species on 4 study pastures on the Santa Rita Experimental Range, 1957-66

Species	Average production	Productivity index[1]
	kg/ha[3]	
Curlymesquite (*Hilaria belangeri*)	6.4	1.04
Sprucetop grama (*Bouteloua chondrosioides*)	24.6	1.23
Hairy grama (*B. hirsuta*)	12.1	1.87
Santa Rita threeawn (*Aristida glabrata*)	9.5	1.86
Slender grama[2] (*Bouteloua filiformis*)	96.0	2.15
Sideoats grama[2] (*B. curtipendula*)	66.0	2.52
Black grama[2] (*B. eriopoda*)	58.7	2.93
Rothrock grama (*B. rothrockii*)	8.1	3.30
Tall threeawns[2] (*Aristida hamulosa*) (*A. ternipes*)	62.4	3.65
Arizona cottontop[2] (*Trichachne californica*)	70.6	4.17
Plains lovegrass (*Eragrostis intermedia*)	10.4	4.57
Lehmann lovegrass (*E. lehmanniana*)	3.8	4.98
Bush muhly (*Muhlenbergia porteri*)	4.5	5.90
Green sprangletop (*Leptochloa dubia*)	23.7	7.78
Tanglehead (*Heteropogon contortus*)	18.0	9.23
Plains bristlegrass (*Setaria macrostachya*)	8.1	9.26
Cane bluestem (*Andropogon barbinodis*)	10.0	9.63

[1]Weight of herbage per hectare per 0.01 percent of basal intercept.
[2]Major species.
[3]Kg/ha = 1.12 (lb/acre).

Table 4.—Chemical composition of Arizona cottontop herbage in percent on a water-free basis

Stage of growth	Authority	Water	Ash	Crude protein	Crude fiber	N-free extract	Ether extract
Young	Fudge and Fraps (1945)	7.49	10.59	8.22	33.39	38.56	1.75
Early mature	Griffiths et al. (1915)	7.85	11.96	9.97	29.97	45.72	2.38
Green mature	Wilson (1931)	3.79	7.98	4.92	32.22	49.43	1.85
Dry	Catlin (1925)	2.81	8.46	4.62	32.62	50.11	1.36
2-3 yrs old	Catlin (1925)	2.47	8.67	4.00	34.33	50.58	1.11

Palatability.—Arizona cottontop has been rated by researchers as moderately high in palatability. For example, McGinnies et al.,[4] based on the work of Lister (1939), ranked cottontop sixth in preference out of 14 perennial grasses for yearlong grazing by cattle, varying by seasons from second for July-September grazing to thirteenth for December-January grazing. Arnold (1942) rated cottontop eleventh out of 19 grasses for cattle. Culley (1937), however, reported that cottontop was definitely selected by cattle through most of the year—more consistently than any other of the 10 most important perennial grasses on the Santa Rita. Canfield (1942) concluded that "Arizona cottontop is a preferred grass in spite of its relatively coarse stems."

More recent data on palatability support the high preference rating indicated by Culley and Canfield. In a 10-year study (Cable and Martin 1975), average use of cottontop was 57%, second highest of all species. The average for all species was 41%. Although cottontop contributed only 13.6% of the total perennial grass production during the 10-year period, nearly one-fourth (22.4%) of the total perennial grass use consisted of cottontop. In the same study, on those transects on which use of all species averaged 10%, use of cottontop averaged 36%, a further indication cattle strongly prefer cottontop.

Response to Grazing

Dormant-season grazing.—Degree of use of 200 individually tagged plants was determined annually on the Santa Rita for 15 years from the height-weight relationship, using the ungrazed height at the end of the summer growing season, and the grazed stubble height the following June. All grazing by domestic livestock occurred during the winter-spring season. Intensity of use varied widely among plants and among years. For example, for the 172 plants that lived 2 or more years after tagging, mean use varied among plants from 16 to 71%. One plant was grazed from 68 to 72% by weight for seven successive winter dormant seasons and was alive and healthy 16 years after tagging. These widely varying intensities of use during the 15-year period had no apparent effect on (1) the number of years the plants lived after tagging, (2) changes in basal area of individual plants, or (3) changes in ungrazed plant height from year to year. Dormant season grazing of Arizona cottontop, at high as well as low intensities, appears to have no detrimental influence on vigor or longevity of individual plants.

Growing-season grazing.—Consistent heavy grazing during the summer growing season adversely affects vigor and productivity of cottontop. It was previously noted that continued heavy grazing reduces Arizona cottontop to a minor component of the perennial grass stand, even where cottontop is well adapted (Canfield 1948). Canfield also reported that an increase in abundance of cottontop is the most conspicuous, if not the first, sign of range recovery under either conservative grazing or total protection. Under good management, cottontop made up 19-31% of the total perennial grass stand. Overgrazing caused a tendency toward dominance of short-lived and short-statured perennial grasses.

Arizona cottontop is apparently as able to maintain itself or increase on conservatively grazed year-long ranges as it does on summer-deferred ranges. Reynolds (1959) reports an increase in cottontop from 0 to 6.1% of total stand between 1937 and 1948 on a summer-deferred range on the Santa Rita Experimental Range, compared to an increase from 3.1 to 15.5% on a yearlong-range grazed conservatively.

More recent data indicate the degree of recovery following a dry year is strongly linked to the average level of grazing use. Thus, on transects where utilization during a 10-year period was heavy (52-59%), increases in perennial grass production following a dry year were greatly suppressed compared to increases where plants were lightly used (21-28%) (Cable and Martin 1975). In terms of absolute production (pound per acre), however, cottontop showed larger increases where use was heavy. This suggests recovery of cottontop was not affected adversely by heavy use. There were wide differences in the levels of herbage production among the four groups of transects, however. The more heavily used groups were also the higher producing groups. When the production data are more properly expressed as percent of production in the initial year, the cottontop data are consistent with those for the other species: largest percentage increases in production following a dry year occurred on transects where plants were used most lightly, and smallest percentage increases on transects used most heavily (fig. 10). The data also suggest that the heavily grazed plants were not able to respond fully to higher rainfall for at least 2 years following a very dry year.

Restrictions in root development caused by heavy grazing are probably involved in the variable rates of recovery following a dry year on plants grazed at different intensities. In an examination of root branching on grazed versus protected cottontop plants, Blydenstein (1966) found grazed plants had 32 root branches on the first 15.2 cm of length, compared to 80 branches on ungrazed plant roots.

Effect of removing the growing point.—A recent study in which growing points of individual culms were removed at different stages of culm development helps to explain the response of cottontop to grazing.

Thirty-two individual culms on field grown plants were selected in July, at the start of the summer rainy season, in each of the following stages of development:

1. Vegetative growing point
2. Early reproductive - panicle less than 5 mm long
3. Early boot - flag leaf blade just fully exposed
4. Late boot - panicle fully developed, ready to exsert
5. Panicle exserted - no axillary shoots visible
6. Panicle exserted - axillary shoot tips showing

The growing points were removed from half the culms in each stage. Lengths of axillary shoots developing on each culm were measured weekly for the following 11 weeks. Numbers and growth rates of axillary shoots increased significantly at all stages of development on culms with growing points removed. Twice as many new axillary shoots appeared on treated culms as on intact culms during the first 4 weeks after treatment (fig. 11). Total length of axillary shoots on treated culms averaged about three times the length on intact culms during the same period, varying from an additional 72 mm/culm for culms treated in the early boot stage to 113 mm/culm for culms treated in the early reproductive stage. By the end of the summer growing season numbers of axillary shoots on intact culms had caught up with those on treated culms, about 1.5 shoots/culm for both, but total length of axillary shoots on treated culms averaged 314 mm, well above the 232 mm for intact culms.

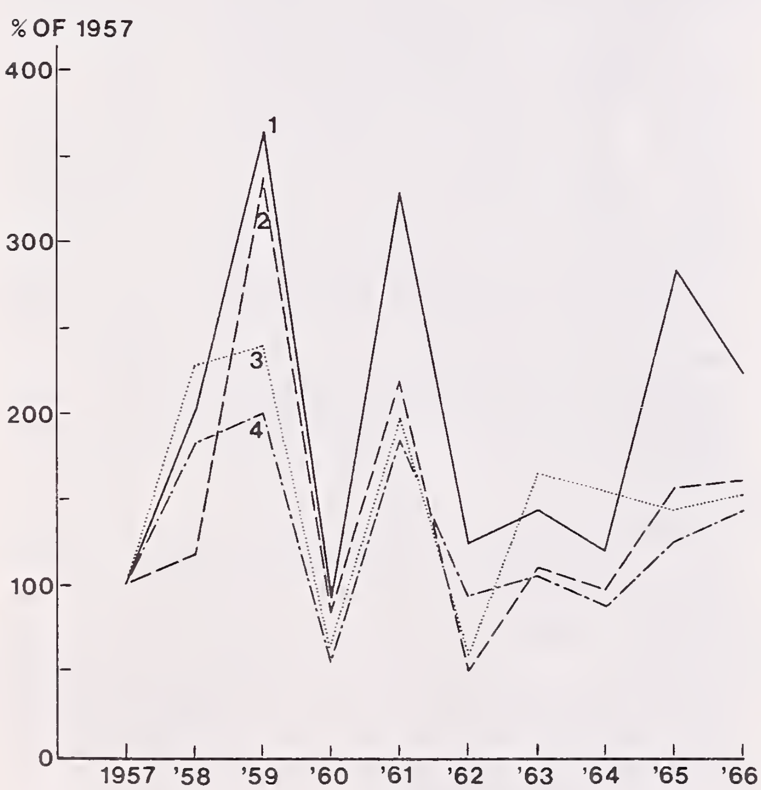

Figure 10.—Arizona cottontop production, as percent of production in 1957, on transects used at different levels for the period 1957-66. Mean 10-year use of cottontop for groups 1, 2, 3, and 4 were 48, 52, 65, and 71 percent, respectively.

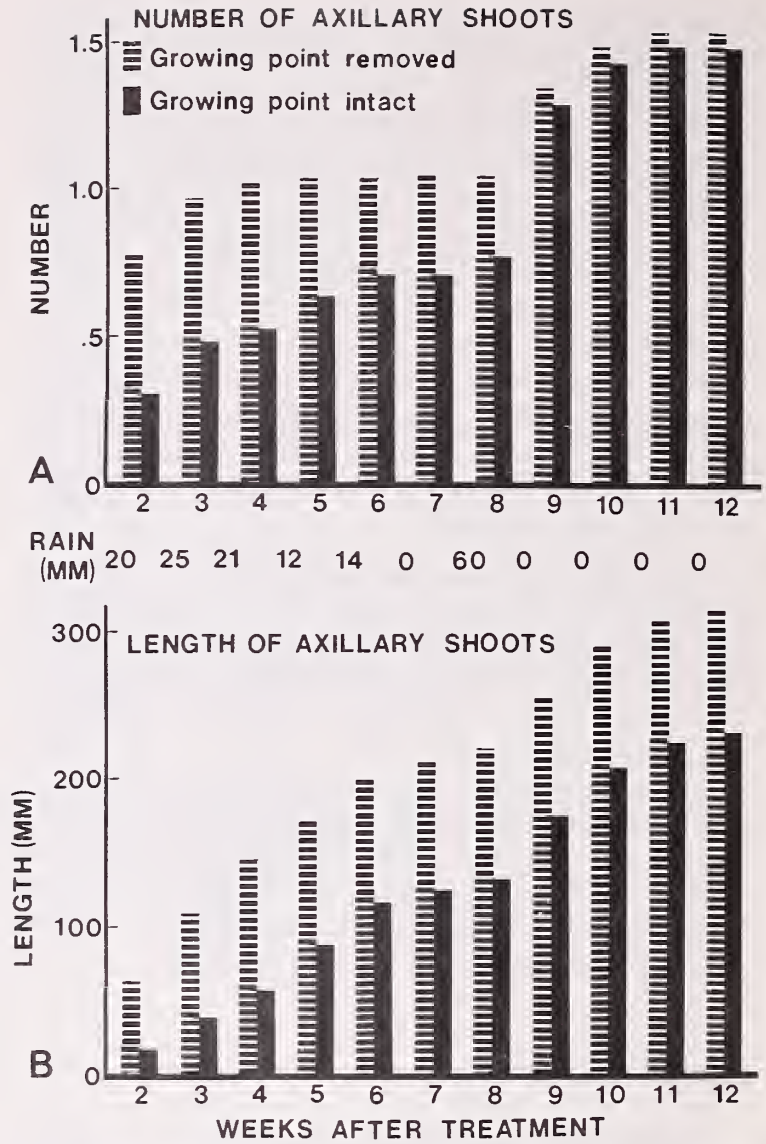

Figure 11.—Number (A) and total length (B) of axillary shoots per culm on successive weeks from July 29 to October 5, for culms with growing points removed and for intact culms.

The inherently weak apical dominance of cottontop permits axillary shoot development even on intact culms, but the growth of axillary shoots is stimulated if the growing points are removed. Hence, cottontop can tolerate relatively heavy grazing use because accelerated growth of axillary shoots after grazing soon offsets the initial loss of leaf surface.

Response to Fertilization

Little information is available on the effect of fertilization on cottontop. Fertilization of semidesert grasslands generally has shown little benefit unless rainfall is above normal in the following summer growing season. In these wetter years, fertilization increases production, protein content, and palatability, and extends the green feed period (Stroehlein et al.

1968, Herbel 1963, Honnas et al. 1959, Holt and Wilson 1961). In one study on the Santa Rita, plots fertilized with 224 or 448 kg/ha of ammonium phosphate produced Arizona cottontop plants 50% taller than on unfertilized plots in a year of above-average summer rainfall. With no fertilizer, plants averaged 7.8 grams per plant; with 224 kg/ha of fertilizer, plants averaged 23.6 grams per plant. Cattle preferred plants fertilized at 224 and 448 kg/ha over those fertilized at 112 kg/ha or not fertilized. There was no difference in the time of seed set, but the seed appeared to be heavier at the higher fertilizer rates (Tixier 1959).

Reseeding

Arizona cottontop has been recommended for reseeding by Cassady and Glendening (1940) on "barren or almost barren sheet-eroded gravelly ridges, characterized by fairly heavy clay soils" and for "deteriorated grassland areas receiving 35 cm or more of rainfall annually." They recommend seeding on contour furrows and covering by raking. They also report cottontop can be successfully transplanted in July, August, February, and March.

Earlier work by Wilson (1931) in New Mexico indicated 6-7 kg/ha of seed planted not deeper than 1.2 cm should give a good stand if the area can be kept relatively weed free. He recommended drilling in the latter part of June, and reported Arizona conttontop gave the best germination of all native forage plants tested. Wilson also noted cottontop seedlings made slower growth than most other plants, especially the annuals. Quicker growing plants soon overtopped and shaded the cottontop seedlings to their detriment.

Glendening (1942), in a study of the effect on germination and emergence of different methods of covering the seed, concluded cultivation was not essential where the soil could be covered with some form of litter. Best germination and emergence was obtained where the ground was covered with open-mesh gauze. About two-thirds as many seedlings were obtained where cut burroweed branches were scattered over the ground surface or where the ground was raked and covered with open-mesh gauze. Covering the soil surface consistently increased soil moisture content and lowered soil temperature.

Anderson et al. (1953) consider Arizona cottontop as one of the more easily established native grasses, if a good seedbed is prepared. It was the most persistent species tested on a droughty site with loose gravelly soil near Nogales, spreading fairly rapidly by volunteer seeding. Anderson et al. reported the fluffy seed can be planted with cotton box hoppers on the seeding equipment. The recommended seeding rate is 5.6 kg/ha of hammermilled seed in the hulls.

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Metric-English Conversion Factors

1 mm	= 0.039 inches
1 cm	= 0.394 inches
1 m	= 39.37 inches
1 ha	= 2.47 acres
1 ka/ha	= 0.89 pounds/acre

Cable, Dwight R. 1979. Ecology of Arizona cottontop. USDA For. Serv. Res. Pap. RM-209, 21 p. Rocky Mt. For. and Range Exp. Stn., For. Serv., U.S. Dep. Agric., Fort Collins, Colo.

This paper summarizes what is now known about the ecology and management of Arizona cottontop, *Trichachne californica,* a palatable, drought hardy, perennial grass that thrives under moderate grazing on semidesert ranges of the Southwest. Perennial culms that produce axillary shoots, favorable response to grazing, long life, and ability to grow both on warm- and cool-season moisture are valuable attributes of this species.

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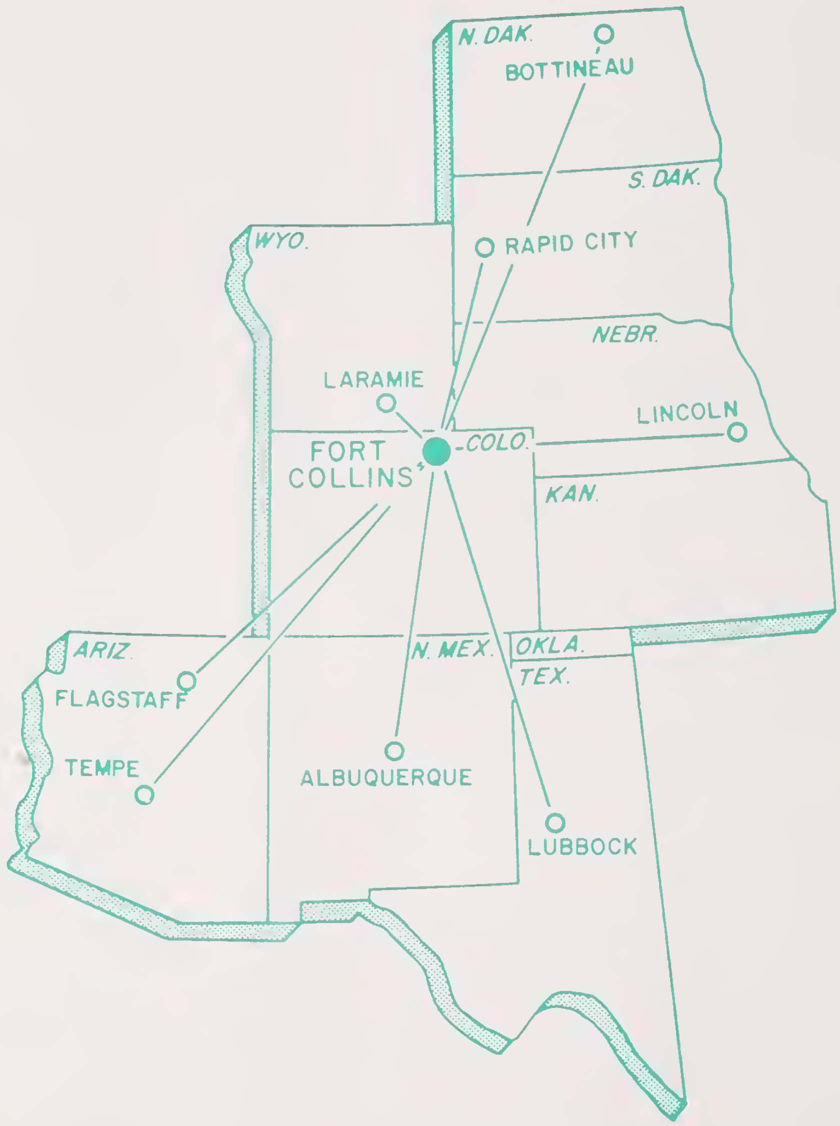
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